Fast Tuner Development for RIA

Spoke Cavity Workshop - Los Alamos National Lab

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Microphonic Effects on the RIA Driver (and RIB) Linacs Strongly Influence the RF Design and Cost

- RIA is not like other linacs where beam loading is comparable to the microphonic detuning
- The microphonic control window for RIA is expected to be on the order of 50-150 Hz, which is greater than the beam loaded bandwidth
  - Microphonics at ~ 7-15 Hz with a multiplier to achieve margin of ~ 10-12

linear accelerator	operating frequency (MHz)	loaded Q	bandwidth (Hz)
CEBAF/Jefferson Lab	1497	2.2×10^6	680
SNS/ORNL	805	7.0×10^5	1,150
APT design/LANL	700	2.2×10^5	3,182
RIA – 115 MHz – U beam	115	8.7×10^6	13
RIA – 345 MHz – U beam	345	1.3×10^7	27
RIA – 805 MHz – U beam	805	8.3×10^8	1

- Light beam loading on the Driver and RIB linacs necessitates that microphonic detuning of the SRF cavities be addressed
  - Heavy ion machines have limited and widely varying beam currents across species driven primarily by ion source considerations
  - Stable operation on species and rapidly retuning the machine are important for customer satisfaction

"Idealized" Generator Power Related to a Q_x Setpoint for a Fixed Beam Current

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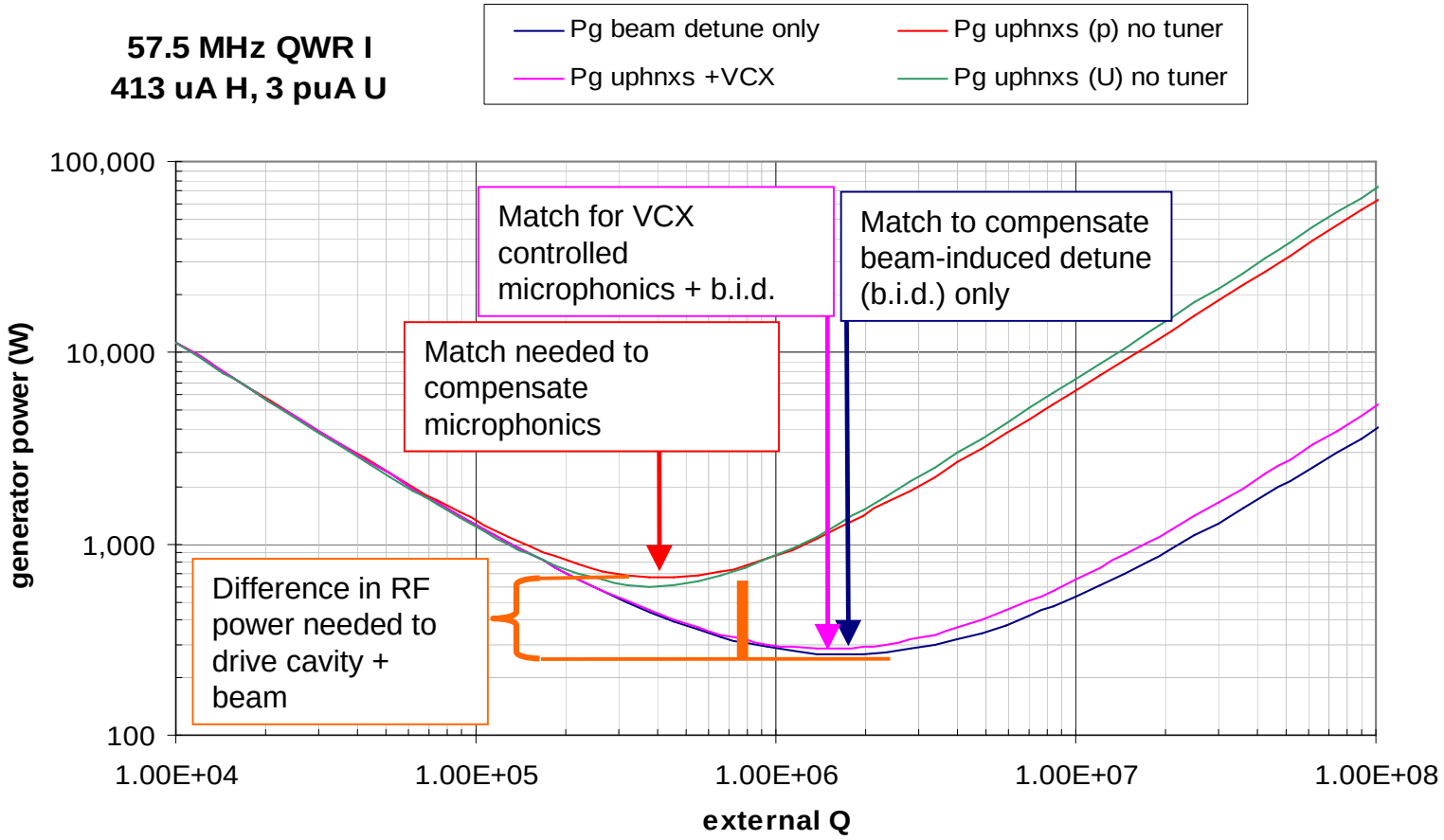
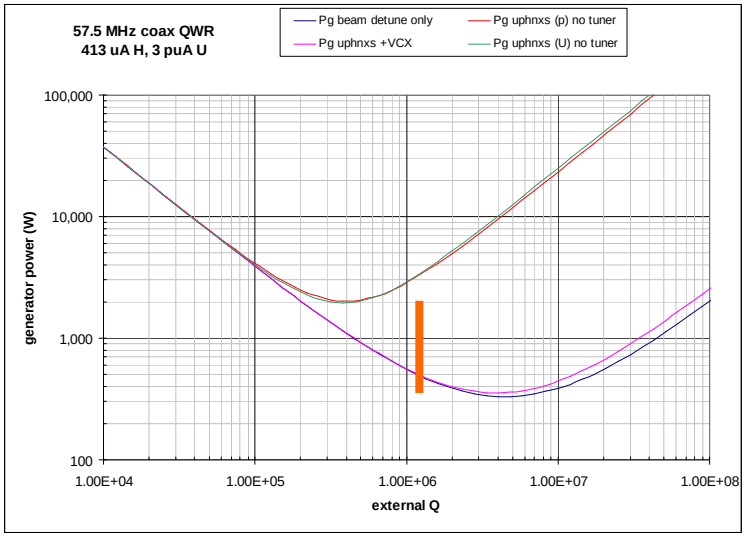
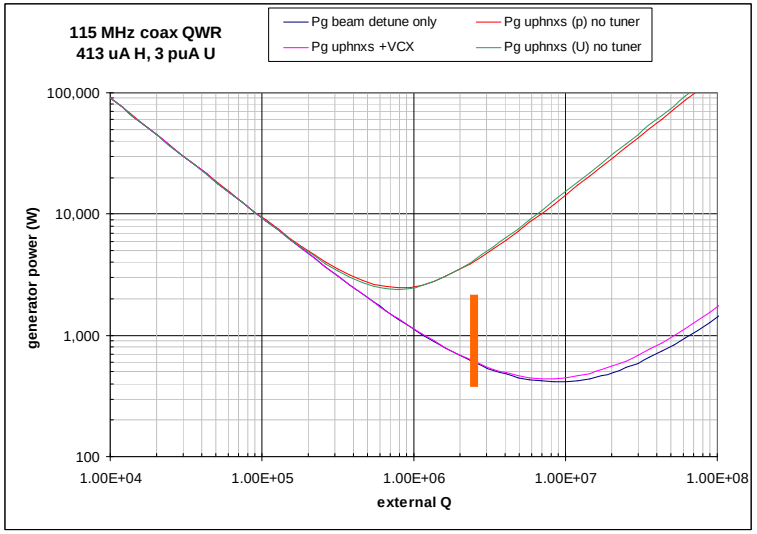
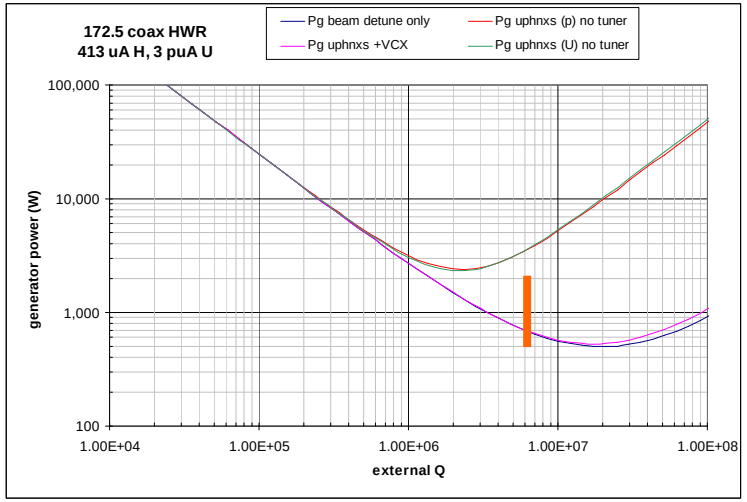


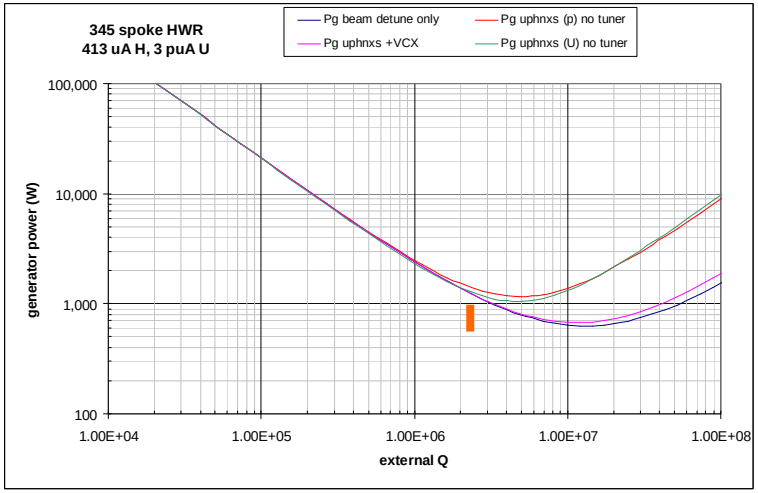
$$P_{gen} = \frac{P_c}{4}\left\{\frac{2I_oR_a}{V_c}\left[\left(1+\frac{Q_x}{Q_0}\right)\cos(\phi) - 2Q_x\delta\sin(\phi)\right] + \left[\frac{(Q_0+Q_x)^2 + 4(Q_0Q_x\delta)^2}{Q_0Q_x}\right] + \left(\frac{I_oR_a}{V_c}\right)^2\frac{Q_x}{Q_0}\right\}$$

Low-β Driver Cavities Power Required Curves from 57.5 - 345 MHz









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805 MHz Elliptical Cavity Power Requirement Curves

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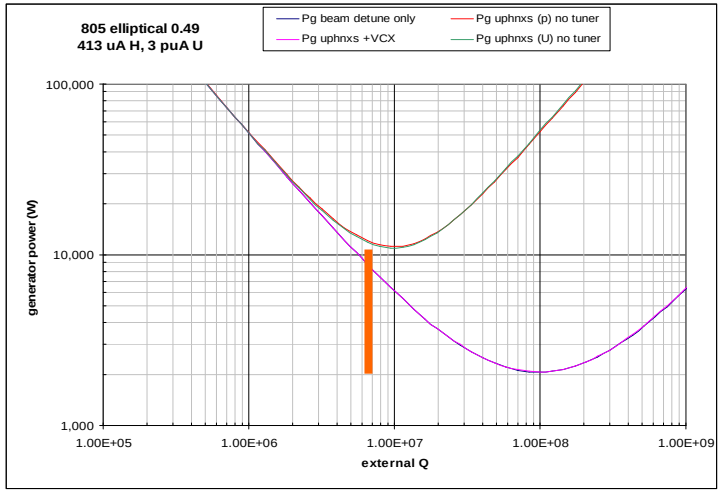

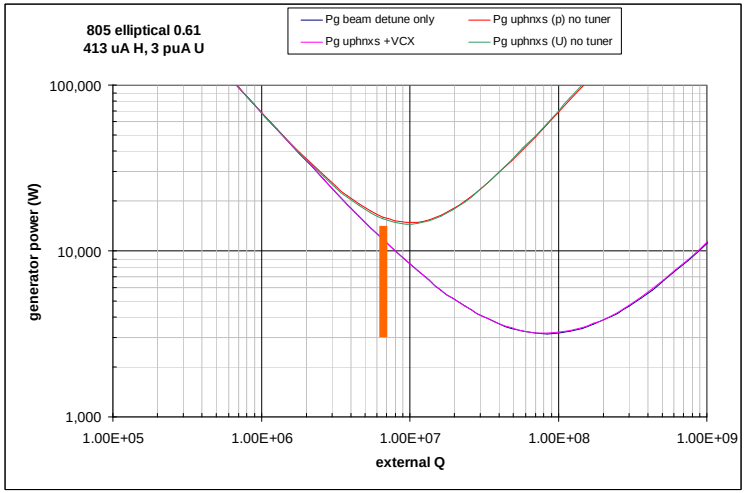

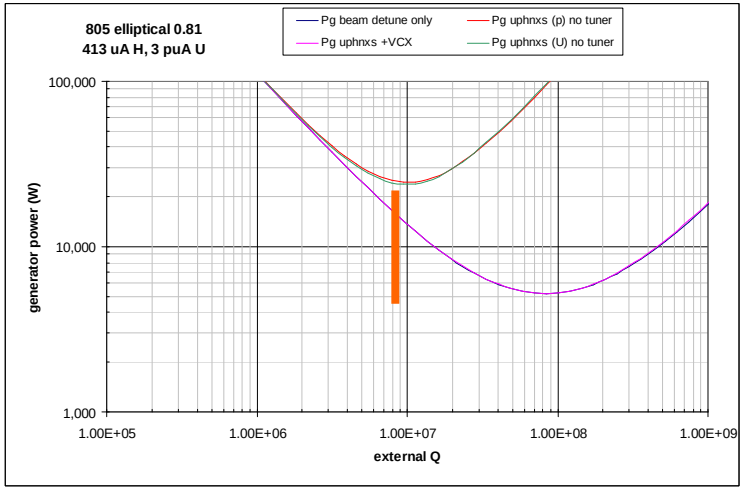

Comparative Summary of Overcoupled and VCX Cases Demonstrating Impact

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	------- Overcoupled Case ------		- VCX Tuner Compensated -	
cavity type	**installed**	**section**	**installed**	**section**
	RF power	**cost**	**RF power**	**cost**
low β	**(W)**	**(k$)**	**(W)**	**(k$)**
57.5	160,000	2,155	30,000	1,160
115	225,000	2,424	45,000	1,576
172.5	520,000	7,522	104,000	3,642
345	160,000	5,508	160,000	5,098
low β subtotal	**1,065,000**	**17,609**	**339,000**	**11,476**
high β				
805 - 0.49	960,000	7,749	240,000	5,039
805 - 0.61	1,920,000	12,412	320,000	8,140
805 - 0.81	1,400,000	7,066	280,000	3,561
high β subtotal	**4,280,000**	**27,227**	**840,000**	**16,740**
LN lines low β				**175**
LN lines hi β				**225**
linac totals	**5,345,000**	**44,836**	**1,179,000**	**28,616**

Low β cost savings: 6.1 M$

High β cost savings: 10.5 M$

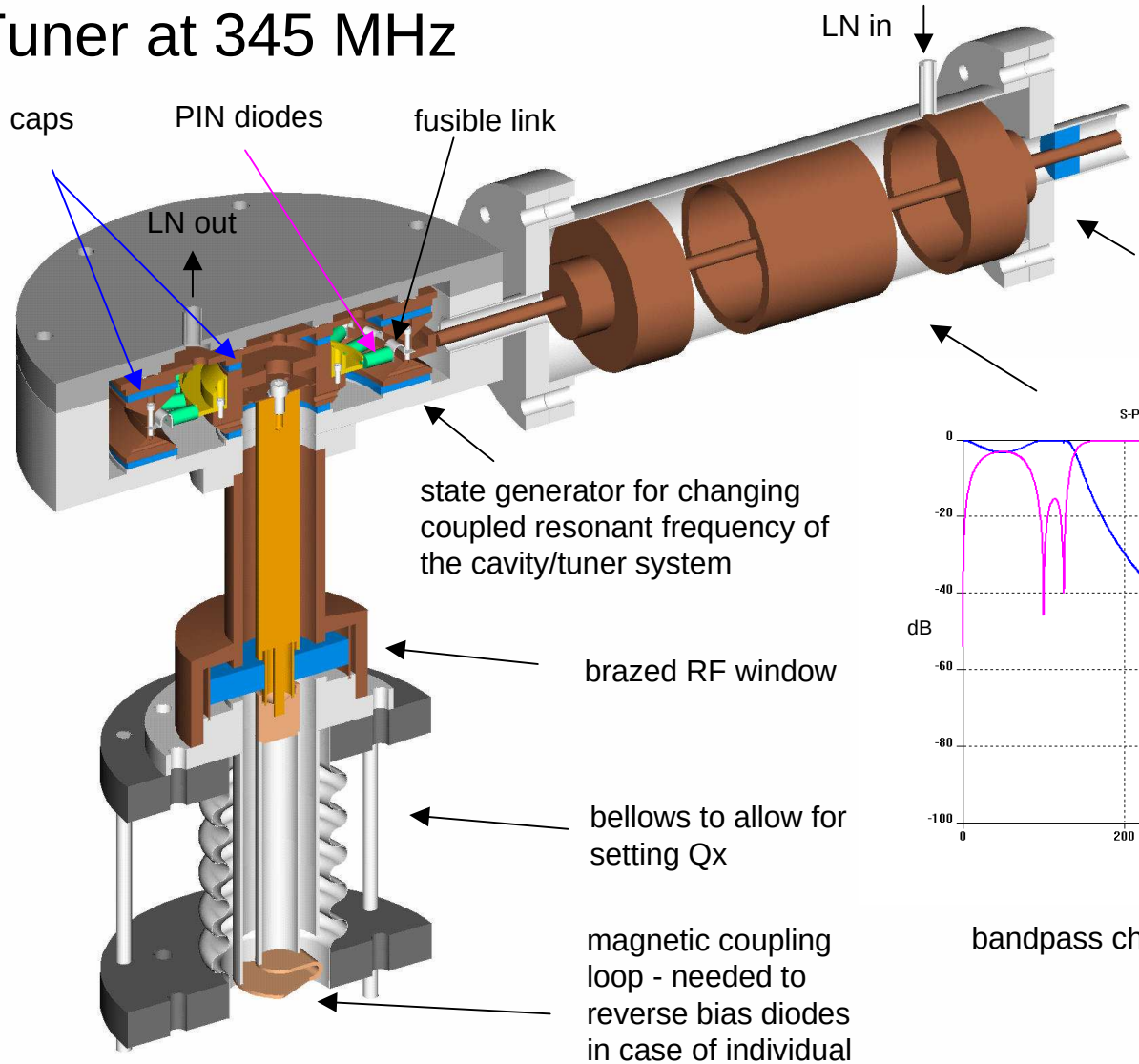
- Reduced cost primarily due to the factor of 3-5 less installed RF power, smaller RF couplers, transmission lines, and components which more than offsets the cost of the tuner and pulser.

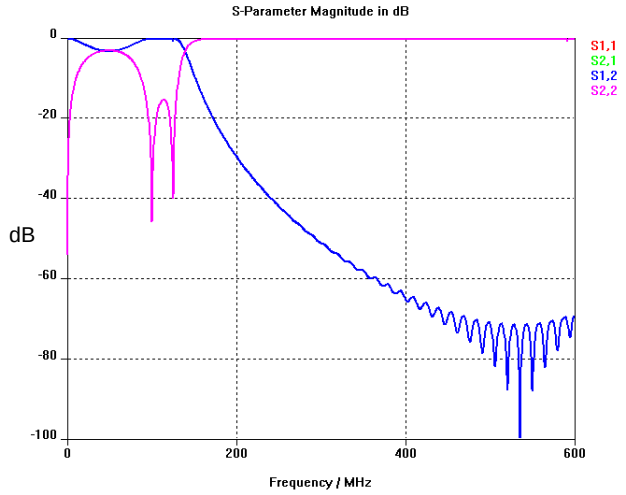
- Costs include estimates for running cryogenic LN lines in the tunnel.

Approaches to Compensate Microphonic Detuning

- Microphonic detuning is more a cost and implementation challenge than a technical show stopper
- It comes down to where the effort and resources are placed:
  - Overcoupling: costly, wastes RF, but is effective
  - VCX fast tuning: efficient, needs further development
  - Cavity stiffening: mechanical engineering design challenge, especially to accommodate slow and bench tuning
- Based on the operational agility and the effectiveness of the VCX fast tuner demonstrated at the ATLAS heavy ion linac, development in this area is being pursued in the baseline design for RIA
  - Phase I: extend ATLAS design to 345 MHz using distributed element model
  - Phase II: explore applicability to elliptical cavities with much higher stored energy and frequency

Design Drawing of Distributed-Element VCX Tuner at 345 MHz





bandpass characteristics of LP filter

Development Work Needed

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- RF modeling (Microwave Studio)
  - voltages on state generator components
  - evaluating impedance at different frequencies
  - determine power densities
  - finish modeling window
- Device prototyping
  - machine parts
  - measure at low power
  - fine tune as necessary
  - test on cavity
- Pulser work
  - evaluate present pulser design
- Additional evaluation work needs to be done looking at applicability to elliptical cavities, as this is where the largest cost savings (and largest development effort) would be